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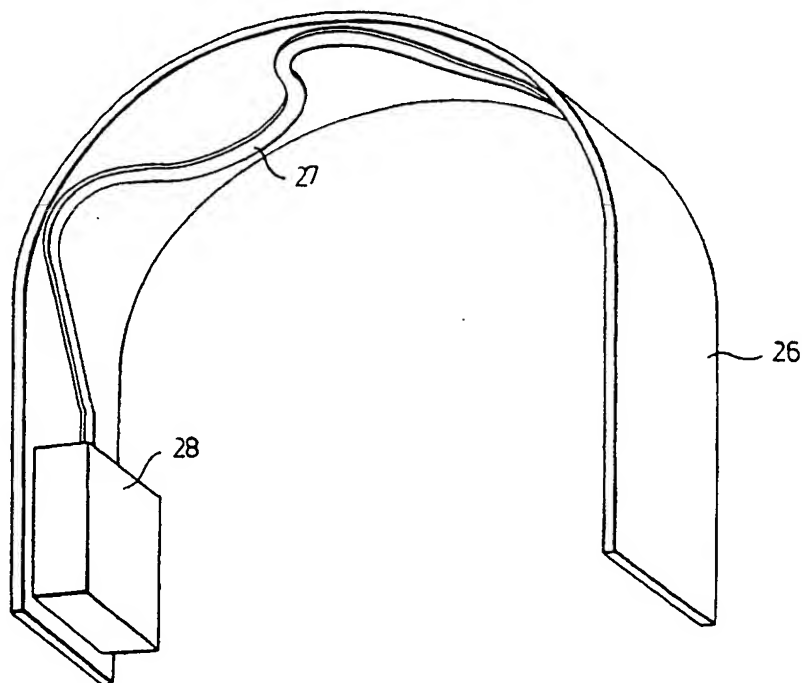
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## (57) Abstract

An antenna device for transmitting and receiving RF waves in at least a first frequency band and adapted to be arranged in a radio communication device. The antenna device comprises a support structure (26), at least one radiating antenna portion (27) carried by the support structure, a circuit carried by the support structure for processing analogue RF signals tapped from or fed to the radiating antenna portion, and coupling means arranged for connecting the circuit to the radio communication device. A radiation shielding device (28) of an electrically conductive material surrounds the circuit at least partially, and the shielding device (28) is functionally integrated with the radiating antenna portion (27) and forms an actively radiating part thereof.



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AN ANTENNA DEVICE AND A RADIO COMMUNICATION DEVICE  
INCLUDING AN ANTENNA DEVICE

FIELD OF THE INVENTION

5  
The present invention relates to an antenna device for transmitting and receiving RF waves in at least a first frequency band and comprising a support structure and at least one radiating antenna portion carried by the support structure.

10  
The invention also relates to a radio communication device including such an antenna device.

15 BACKGROUND OF THE INVENTION

In the radio communication systems of today there is an ever increasing demand for making the user devices smaller. This is especially important when it comes to handportable terminals, e.g. portable phones. The design of the handportable terminals must permit the terminals to be easily and rapidly manufactured at low costs. Still the terminals must be reliable in use and exhibit a good performance.

25  
It is well known that the size of an antenna is critical for its performance, see Johnsson, Antenna Engineering Handbook, McGrawHill 1993, chapter 6. The interaction between antenna, phone body and the close-by environment, such as e.g. the user himself, will become more important than ever.

30  
This puts requirements on the antenna device to be compact, versatile and to have good antenna performance. It must also be robust, stable, easy to mount, easy to connect, and arranged so as to efficiently use the

35

available space. Interest has also been focused on antenna devices mounted inside the housing of hand-portable terminals. Thereby, protruding antenna parts are avoided.

5

The radiating properties of an antenna device for a small-sized structure, e.g. for a handportable terminal, such as a portable phone, depends heavily on the shape and size of the support structure, e.g. a printed circuit board, PCB, of the phone, and also on the phone casing. All radiation properties, such as resonance frequency, input impedance, radiation pattern, impedance, polarization, gain, bandwidth, and near-field pattern are products of the antenna device itself and its interaction with the PCB and the phone casing. On top of this, objects in the close-by environment affects the radiation properties. Thus, all references to radiation properties made below are intended to be for the whole device in which the antenna is incorporated.

20

What has been stated above is true also with respect to radio communication systems used in other apparatus than portable phones, such as cordless telephones, telemetry systems, wireless data terminals, etc. Thus, even if the antenna device of the invention is described in connection with portable phones it is applicable on a broad scale in various radio communication apparatus.

25

As the rate at which new models of portable phones are presented is increasing, the time from start of the development of a new model to the start of production and marketing of the same has been drastically shortened during the last few years. Further, there is a demand for a reduction of the manufacturing costs at the same time as the technical requirements are in-

30

35

- creasing which necessitates more functions to be included in each unit. Further, the different parts and units must be manufactured to fit well into the method of production. Simple interfaces is one key feature to simplify the assembly of the final product from different parts manufactured at different places.

For all types of radio communication devices, the part between the antenna and the active components of the RF front-end is critical for the total performance of the radio communication device. This is because all losses that are introduced here are critical from a system point of view. On the receiver side losses that occur before the Low Noise Amplifier (LNA) degrades the sensitivity of the receiver. On the transmitter side, losses that occur after the Power Amplifier (PA) causes degradation of the transmitted power, forcing the PA to transmit at a higher output level.

For portable terminals with energy provided by battery power, these factors are even more critical. Reduced receiver sensitivity causes the device to perform worse in areas with low signal levels. A higher output level from the PA increases the energy consumption from the battery, thereby reducing the available active operation time.

Modern manufacturing methods for devices, such as portable telephones, is based on modules that are assembled in a final assembly line. This procedure requires simple and reliable interfaces between the modules. This typically implies that the interfaces have large tolerances, making them hard to specify tightly. Specifically, this means that the loss in the interface can be quite large.

In order to obtain improvements in these respects some new principals for designing and assembling the products are necessary. Among them, the method of installing the antenna device and at least some of the required RF components must be improved.

Resistive losses, for instance, can be substantially reduced by shorting the connection lines between the antenna elements and the required active analogue components, such as filters, amplifiers, etc. This can be obtained by mounting the components close to the antenna elements, and preferably on a common support structure in order to form a separate antenna module.

This is of specific interest for future Software Radio, SR, architectures where the function of many traditional RF parts in the terminal are included in the software controlling the signal processor. The number of analogue RF parts, especially analogue filters, are strongly reduced in the software radio architecture. The ideal SR converts the analogue signal to/from digital data as close as possible to the antenna elements. However, some components, such as the Low Noise Amplifier(s), LNA, the filters to reduce strong interfering signals and noise, the Power Amplifier(s), PA, and the duplexers to separate transmitting and receiving signals, must still be made as analogue components. Thus, it would be a great advantage if the radio communication device could be assembled from modules, for instance a complete RF module including all analogue RF parts and the antenna, and a digital module comprising the signal processor, and a simple interface therebetween.

In more detail a number of advantages can be obtained by such a proposed complete RF module. One is the

reduction of losses mentioned above. Another is the simpler RF interface enabled by feeding a lower power from the transmitter circuitry in the digital module to the RF power amplifier in the RF modul, and by amplifying the received power before feeding it from the low noise amplifier in the RF module to the receiver circuitry in the digital module. The proposed position of the interface between an antenna module and a radio module means that losses in the interface is not critical. This reduces the requirements on the tolerances of the interface (e.g. the contact pins) so that a more favourable assembly method can be chosen.

A further advantage can be the simplification of the duplexer, triplexer, etc. function if more than one antenna is used, e.g. separate receiving and transmitting antennas. To implement this in an efficient way it is necessary that this function is part of a complete RF module. An additional advantage is obtained by a mechanical integration in order to utilize the volume below the antenna element as well as possible. By using the physical area of the antenna module to mount some components needed for processing of the analogue signals the total space required is reduced. This is because the positions of the components can be chosen so that they have a minimum impact on the antenna performance. It is an advantage if the interaction between different components can be controlled, both for antenna performance and for interference, intermodulation, etc.

Preferably, the antenna structure should conform to the exterior casing of the radio communication device. However, the most of the improvement in volume below the antenna element when going from a flat antenna element to an element adapted to the form of the casing



is being obtained already when using an element arranged on a carrier having a single curvature only.

#### SUMMARY OF THE INVENTION

5

In this disclosure it is to be understood that the antenna device of the invention is operable to transmit and/or receive RF signals. Even if a term is used herein that suggests one specific signal direction it is to be appreciated that such a situation can cover that signal direction and/or its reverse.

10

A main object of the present invention is to provide an antenna device which is easy to manufacture, easy to mount and which enables an efficient use of the available space, and has good antenna performance.

15

An other object is to provide an antenna device in which internal losses due to the resistivity in connection lines have been reduced.

20

A further object of the invention is to provide an antenna device which can be formed as an easily installable antenna module also including processing capacity for analogue RF signals.

25

An additional object of the invention is to provide an improved antenna device with processing capacity for analogue RF signals which can be formed as a module which via a readily connectable interface can be connected to a signal processor of a software radio module.

30

A further object of the invention is to provide an antenna device comprising matching circuits so as to let said antenna means be connectable to a connection

35

point having a specific, matched, impedance, for instance 50 ohm.

A still further object of the invention is to provide an antenna device which is designed as a built-in module.

Another object of the invention is to provide an antenna device which can be adapted to the shape of the casing of the radio communication device it is to be installed in.

These and other objects are attained by an antenna device as claimed in claims 1-48.

Claims 31-48 of these claims relate to antenna devices of the kind generally named Planar Inverted F-Antennas, PIFA, modified in accordance with the present invention. The space occupied by such a modified PIFA is more effectively used since circuitry is accommodated inside the antenna. An other advantage of this design of a PIFA is that such circuitry can be placed in the immediate vicinity of the antenna feeding point, thus avoiding transmission losses.

According to a preferred embodiment of the invention an antenna device is provided comprising duplexer, or switch means for combining transmitting and dividing receiving frequencies, filter means for filtering transmitting and receiving frequencies, low-noise amplifier means for amplifying the receiving frequencies and, possibly, power amplifier means for power amplifying the transmission frequencies, as well as a connection device for easy connecting the signal lines to a connection point having a specific impedance, for

instance 50 ohm, and further coupling the signals to RF circuitry in the radio communication device.

5 According to an other embodiment of the invention an antenna device is provided comprising means for securely holding a SIM-card and connecting said SIM-card to circuitry in the radio communication device.

10 An additional object of the invention is to provide a radio communication device comprising an antenna device manufactured to fulfil the main object of the invention mentioned above. This object is obtained by a radio communication device as claimed in claim 49.

15 An advantage, according to one embodiment of the invention, is that the space occupied by a PIFA is more effectively used since circuitry is accommodated inside the antenna which otherwise would have to be placed in the surrounding areas.

20 An other advantage, according to one embodiment of the invention, is that circuitry essential for the effective operation of the antenna can be placed in the immediate vicinity of the antenna feeding point, thus  
25 avoiding transmission losses. The feeding point being the point inside said cavity connecting said feeding means to said feeding post.

30 Another advantage, according to one preferred embodiment of the invention, is that it is possible to achieve a matched antenna having connector means with a specific impedance, for instance 50 ohm.

35 The invention is described in greater detail below with reference to the embodiments illustrated in the appended drawings. However, it should be understood that the

detailed description of specific examples, while indicating preferred embodiments of the invention, are given by way of example only, since various changes and modifications within the scope of the claims will  
5 become apparent to those skilled in the art reading this detailed description.

#### BRIEF DESCRIPTION OF THE DRAWINGS

10 Figure 1 is a diagrammatic plan view of an embodiment of an antenna device according to the present invention.

Figure 1a and b is a sectional view and a perspective  
15 view of the antenna device of figure 1a, respectively.

Figure 2 is a diagrammatic plan view of an antenna device comprising a slot antenna element.

20 Figure 3 is a diagrammatic plan view of an antenna device comprising a patch antenna element.

Figure 4 is a diagrammatic perspective view of a curved antenna element in accordance with the present inven-  
25 tion.

Figure 5 is a diagrammatic block diagram of an antenna module for transmitting and receiving RF waves according to a preferred embodiment of the present inven-  
30 tion.

Figure 6 shows a diagrammatic view of an antenna device according to a further embodiment of the invention in a cross-sectional view.

35 Figure 7 shows a diagrammatic perspective view of an

antenna device according to a further embodiment of the invention;

5 Figure 8 and 9 show diagrammatic plan views of antenna devices according to additional embodiments of the invention where part of the top of each antenna device has been lifted away for sake of clarity.

10 Figure 10-13 show diagrammatic sectional side views of antenna devices according to other embodiments of the invention.

15 Figure 14 shows a diagrammatic top view of an antenna device according to a further embodiment of the invention.

20 Figure 15 shows a diagrammatic perspective, partly ghost view of a GPS antenna device according to an embodiment of the invention.

25 Figure 16 shows a diagrammatic sectional side view of an additional embodiment of an antenna device according to the present invention employing a traditional hot-wire feed.

30 Figure 17 shows a diagrammatic sectional side view of a further embodiment of an antenna device according to the present invention having a smooth curve line.

#### 30 DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

35 With reference to Figure 1, a radiating antenna element 1 on a carrier 2 included in an antenna device for transmitting and receiving RF waves is diagrammatically shown. In this embodiment the antenna element 1 is of meander form. The carrier 2 can be relatively thin and

is preferably made from a dielectric polymeric sheet material. ~~The carrier can be stiff but can also be flexible so that it can be shaped so as to closely conform to the casing of the radio communication device~~ for instance a portable telephone, it is to be arranged in.

The antenna element 1 is illustrated as a receiving antenna connected to a Low Noise Amplifier, LNA, 3, but can just as well be a transmitting antenna. The LNA is provided with an output line 14 for amplified RF signals.

In accordance with the present invention the LNA is mounted very close to and on the same carrier 2 as the antenna element 1. This means that losses in the RF signal path between the antenna element 1 and the LNA 3 are substantially reduced compared to devices in which the LNA is positioned on a Printed Circuit Board, PCB, of the radio communication device spaced from the antenna. It is advantageous to reduce these losses as losses occurring before the LNA degrades the sensitivity of the receiver.

In order to reduce the interaction between the antenna element 1 and the LNA 3, or other analogue components mounted on the carrier 2 a shielding can 4 is arranged to surround the LNA at least partly. The shielding can is made of an electrically conductive material and, in accordance with the present invention, the feed line 5 of the antenna goes directly into the shielding can 4 which is mounted very close to the antenna element 1. Thus, the shielding can 4 is functionally integrated with the antenna element 1 and will act as an actively radiating part of the antenna.

Figures 1a and b show a sectional view and a perspective view, respectively, of the antenna device of Figure 1a.

5 The antenna device which forms a readily installable module can easily be fitted in the casing of a radio communication device and its output is connected to additional receiver circuitry by means of a simple interface. As the received RF signals are amplified  
10 before they are passed through the interface the design of the interface is not as critical as it is in cases where it should handle un-amplified RF signals to be fed to a LNA positioned on a PCB of the radio communication device, for instance.

15 Figure 2 illustrates a slot antenna element 6 including a conductive sheet 7 provided with a RF radiating slot 8. In this embodiment the antenna element operates as a transmitting antenna and RF signals are supplied from a  
20 Power Amplifier, PA, 9 which feeds the antenna element with amplified RF signals across the slot 8. This is indicated by means of a contact point 10 between the signal feed line 11 and the conductive sheet 7 in which the slot 8 is provided.

25 The shielding can 4 surrounding the PA 9 is mounted as an integrated part directly on the antenna element 6 and in galvanic contact with the conductive sheet 7. Thus the shielding can operates as a part of the  
30 conductive sheet 7.

The PA 9 is supplied with transmitting RF signals via an input line 15 connected to transmitting curcuitry of a radio communication device via a simple interface  
35 (not shown). The design of that interface is simplified because it has not to be designed for handling ampli-

fied high power RF signals. The position of the PA on the antenna element 6 and after the interface also reduces losses of the amplified signals which is important. Otherwise such losses require the PA to transmit at a higher output level. This should increase the energy consumption from the battery powering the PA and should accordingly reduce the available active operation time of the radio communication device.

Figure 3 illustrates a RF transmitting antenna device corresponding to that of figure 2 but in which the slot antenna element has been replaced by a patch antenna element 16. The same reference numerals as in figure 2 have been used on corresponding parts. The PA 9 feeds the patch 16 with RF signals via a feed post 10 which passes through an opening 17 in the patch, and down towards a ground plane (not shown). The PA 9 and the shielding can 4 are mounted directly on the patch 16 and the shielding can is galvanically connected to the patch 16. Thus, the shielding can 4 is integrated with the patch 16 and will operate as an actively radiating part thereof. The shielding can can also be formed by a part of the patch 16 itself so that a cavity is formed between the patch and a supporting carrier, not shown. In that case the PA 9 is positioned in said cavity.

The above mentioned antenna elements have only been shown as representing preferred examples and the invention is not limited to the use of any specific form or any specific way of feeding an antenna element. Further, only one analogue RF component or circuit has been shown to be integrated with the respective antenna element and shielded by a shielding can. However, in accordance with the present invention any or all analogue RF components of the receiving and the transmitting circuitry of a radio communication device can



be mounted together with the antenna element to form an easily manufactured antenna module which is readily installable in a radio communication device.

5 Figure 4 shows an antenna device in accordance with the present invention formed as a curved antenna module 26. The curvature has been adopted to the design of the radio communication device in which the antenna module is intended to be arranged. The module shown in the  
10 figure is shaped to fit into a portable phone. The carrier can be a flexible substrate which is easily adoptable to any design of a casing. A meandering antenna element 27 is provided on the concave surface of the carrier and connected to a shielding can 28 in  
15 which one or more analogue RF components are mounted. The shielding can is connected to and functionally integrated with the antenna element. The components in the can 28 can be readily connected to the remainder  
20 circuitry of a radio communication device via a simple interface (not shown). The meander element can be replaced by any other radiating antenna element, such as a patch element or a slot element, or a combination of different kinds of antenna elements.

25 As an alternative to being provided on the concave surface of the carrier the antenna element can be provided on the convex surface as well. Further, a first portion of the radiating antenna element can be on the concave surface and a second portion can be on  
30 the convex surface.

The shielded analogue components or some of them can be mounted on the convex surface, preferably in recesses. Antenna elements and components on opposite sides of  
35 the carrier can be interconnected by means of connecting lines passing through holes in the carrier.

The carrier 26 can be excluded and the antenna element and the shielding can be provided directly on the inner surface of for instance the back part of a divided casing of a portable telephone. The antenna element can  
5 be composed of a thin electrically conductive film which can be adhered to the desired surface.

The shielding can has been shown as a closed box provided with openings required for connection lines.  
10 However, the box can be replaced by a shield in the form of a tunnel or the like. The walls of the shield need not be completely closed, but can be provided with openings provided the greatest dimension of the openings is substantially smaller than  $\lambda/2$  of the RF frequency used.  
15

Figure 5 illustrates a preferred RF antenna module according to the present invention. The module 30 comprises separated RF transmitter (TX) 31 and RF  
20 receiver (RX) 32 sections.

The antenna module 30 is the high frequency (HF) part of a soft ware radio communication device (not shown) for transmitting and receiving radio waves. Thus,  
25 antenna module 30 comprising all analogue components is preferably arranged to be electrically connected, via a relatively simple interface, to a digital signal processor of the radio communication device.

30 The antenna module 30 is preferably supported on a carrier 33 which may be a flexible substrate, a MID (molded interconnection device) or a PCB. Such an antenna module PCB may either be mounted, particularly releasably mounted, together with a PCB of the radio  
35 communication device side by side in substantially the same plane or it may be attached to a dielectric sup-

porting means mounted e.g. on the radio device PCB such that it is substantially parallel with it, but elevated therefrom. The antenna module PCB can also be substantially perpendicular to the PCB of the radio communication device, or it can have a three-dimensional form.

The transmitter section 31 includes an input line 34 for receiving a digital signal from a digital transmitting source of the radio communication device. The input line 34 is connected to a digital to analogue (D/A) converter 35 for converting the digital signal to an analogue signal. The converter 35 is further connected to a power amplifier (PA) 36 for amplification of the frequency converted signal. An upconverter (not shown) for upconverting the frequency of the analogue signal to the desired RF frequency can be arranged between the D/A and the PA. Power amplifier 36 is further connected to a transmitter antenna element 37. A filter (not shown) may be arranged in the signal path before or after the power amplifier.

A device 38 for measuring a reflection coefficient, e.g. voltage standing wave ratio (VSWR), in the transmitter section is connected between power amplifier 36 and the transmitter antenna element 37.

A switching device 39, preferably a switching matrix of MEMS (Microelectromechanical System switches), is connected between the SWR and the transmitting antenna structure 37, which is switchable between a plurality of (at least two) antenna configuration states, each of which is distinguished by a set of radiation related parameters, such as resonance frequency, input impedance, bandwidth, radiation pattern, gain, polarization, and near-field pattern.

The receiver section 32 includes a receiving antenna element 40 for receiving RF waves and for generating an RF signal in dependence thereof. The receiving antenna element 40 is switchable between a plurality of (at least two) antenna configuration states, each of which is distinguished by a set of radiation related parameters, such as resonance frequency, input impedance, bandwidth, radiation pattern, gain, polarization, and near-field pattern. A switching device 41 is arranged in proximity thereof for selectively switching the antenna element between the antenna configuration states. The switching of the antennas between a plurality of antenna configuration states is further detailed in our co-pending Swedish patent application No. 9903942-2 "An antenna device for transmitting and/or receiving RF waves", filed on October 29, 1999, which application hereby is incorporated by reference. The antenna element 40 is further connected to one or several low noise amplifiers (LNA) 42 for amplifying the received RF signal.

If reception diversity is used the signal outputs from the low noise amplifiers 42 are combined in a combiner 43. The diversity combining can be of switching type, or be a weighted summation of the signals. Two or more diversity branches can be used. A downconverter (not shown) for downconverting the frequency of the signal can be connected before an analogue to digital (A/D) converter 44 for converting the received signal to a digital signal. The digital signal is output on an output line 45 to digital processing circuitry of the radio communication device. The diversity function can, alternatively, be included in the digital part. This requires separate receiver circuits for each diversity branch.

According to the embodiment of the invention shown in Figure 5 the transmitter section 31 and its antenna element 37, and the receiver section 32 and its antenna element 40 are arranged on a common carrier 33 to form an easily manufactured and readily installable antenna module. The module comprises all analogue components and is intended to be connected to a digital processor unit via a rather simple interface (not shown).

10 In order to avoid disturbances between the components of the transmitter section and the components of the receiver section, and between the components and the antenna elements, shielding cans 46 and 47 are arranged to shield the components of the respective section. The  
15 shielding cans are connected to the antenna elements as has been described earlier.

Each shielding can 46, 47 can be divided into two or more compartments by partition walls 48, 49 to avoid  
20 disturbances between components in each section.

The invention may well be used for modifications of antenna devices of the kind generally named Planar Inverted F-Antennas, PIFA, and some preferred embodi-  
25 ments of such modified PIFA elements are shown in the Figures 6-17.

Figure 6 shows an antenna in a cross-sectional view according to a preferred embodiment of the invention  
30 where a PCB (Printed Circuit Board) is denoted 101. A ground plane means 102 is located on one side of the PCB 101 and on the other side is a circuit layout 103 located. An antenna support structure 104 is coated with a conductive layer 105. The support structure 104  
35 is connectable to a connector means 106. The connector means 106 may for instance consist of metallic hooks

107 with spring action to grip the support to firmly  
fix the support structure 104 in position and elec-  
trically couple the ground plane means 102 to the con-  
ductive coating 105. The coupling means 106 further  
5 comprises male connector means 108 arranged for co-  
operating with female connector means 109 located and  
fixed in connection with said support structure 104.  
The male connector means are connected to the circuit  
layout diagram 103 for further coupling to circuitry  
10 located elsewhere on the PCB 101.

The support structure 104 has a cavity, or a substan-  
tially confined space 114. Since the support structure  
104 is substantially completely surrounded with a  
15 conductive coating 105, which is coupled to a ground  
plane means 102, the space 114 constitutes a Faraday  
cage. This space 114 is thus shielded from magnetic and  
electric radiation and is therefore particularly suit-  
able for housing analogue RF circuitry 110 of the  
20 antenna device.

The RF circuitry 110 is connected through the female  
connector means 109 and the male connector means 108 to  
circuitry located elsewhere on the PCB 101. A feeding  
25 line 111 is also connected to the female connector  
means 109, for further connection through the male  
connector means 108 to circuitry (not shown) located on  
the PCB 101. It is thus clear that the male and female  
connector means 109, 108 may, in their turn, have one  
30 or more individual connector means for connecting  
different signals. The connector means 108, 109 may  
constitute an interface between analogue circuits in  
the cavity and digital processor circuits elsewhere on  
the PCB 101.

35

The feeding line is further connected to a feeding  
point 112 which is connected to a conductive feeding

post 113. The conductive feeding post 113 is extending down towards the ground plane means to constitute a capacitive coupling with said ground plane means 102. So is a planar inverted F-antenna construed having an inner shielded space suitable for mounting analogue RF components. The shielding conductive layer is completely integrated with a radiating antenna surface.

Figure 7 shows a diagrammatic perspective view of an other embodiment of the invention. A support structure 201 is shown in "look through" fashion to reveal the arrangement inside the antenna means. An interface connector means 202 firmly grips and connects the support structure 201 to a PCB 203. A ground plane means 204 on the top side of the PCB is connected, through the coupling means 202, to a conductive coating 205 on the support structure 201. First, second and third connector means, 206, 207 and 208 are coupling first, second and third circuitry 209, 210 and 211 located in a cavity 212, defined by said support structure 201, to circuitry (not shown) located outside said cavity 212. The cavity with its surrounding conductive coating defines a Faraday cage.

A feeding point 213 is connected to said second and third circuitry 210 and 211, which divides the signal in receiving and transmitting signals. The feeding point is connected to the conductive coating 205 as is a conductive post 214, extending downwards towards the ground plane means 204 and substantially across the complete width of the support structure 201. The feeding point is connected to the conductive feeding post, and the conductive feeding post may be connected to the ground plane means or may define a capacitive coupling with said ground plane means.

Figure 8 shows a diagrammatic view according to a further embodiment of the invention in top view where the top part has been cut away. A support structure of a dielectric material 301 has a conductive coating 302. Circuitry 303 is connected through first and second connection means 304, 305. Circuitry 303 is any analogue circuitry which is conveniently positioned inside said support structure 301. The first and second connection means may be any means for electrically connecting one or several signals to said first and second circuitry 302 and 303, such as twisted pair cable, stripline, micro stripline, coplanar wave guide etc. A feed line 306 is connected, at one end to coupling means (not shown) for further connection to RF circuitry and, at the other end to a feeding point 307 which is connected to a conductive post 309, shown with a dotted circle is extending down towards a ground plane means (not shown) making a capacitive coupling with the same.

20

Figure 9 shows a diagrammatic view according to a further embodiment of the invention in top view where the top part has been cut away. In this embodiment a feeding point 402 is connected to a duplexer 401. The feeding point 402 is located above, and connected to, an elongated conductive post 403 indicated by dotted lines which extends down towards a ground plane means (not shown). The duplexer 401 separates transmitting and receiving RF signals and couples the receiving signal to a filter 404, a low-noise amplifier 405 and further through interface means (not shown) to the receiving circuitry (not shown) located in a portable radio communication device (not shown). Similarly the RF transmitting signal is received from the transmitting circuitry of the radio communication device, coupled to a filter 406, to the duplexer 401 and fed



through the feeding point 402. Possibly, also matching means might be included in the arrangement. Thus a planar inverted F-antenna is achieved, which supplies a connection with separated transmitting and receiving  
5 signals, comprising amplification for the receiving signal at the closest possible location to the receiving point of the antenna, which is matched to a 50 ohm impedance.

10 In figure 10, a diagrammatic sectional side view of a further embodiment according to the invention is disclosed. A support 501 is mounted on a PCB 502 having a ground plane means 503 on the surface facing the support 501 and a circuit layout 504 on the opposite  
15 surface. Said support having a conductive coating 505 on a first side, orthogonal to said ground plane means 503, and on a second side substantially facing said ground plane means. Said conductive coating being electrically coupled to said ground plane means 503.  
20 Said coating 505 is in electrical contact on all sides with a stiff conductive metallic sheet 506 forming an integrated part of the radiating antenna and defining together with said conductive coating a shielded space 507 having one open side 508. Inside said space is a  
25 first circuit 509 located. A feedline 510 is feeding RF signals to a feed point 511. Said feed point 511 is in conductive contact with a conductive post 512 extending down towards said ground plane means 503 for achieving capacitive coupling.

30 Figure 11 shows a diagrammatic cross-sectional side view of a further embodiment according to the invention. The embodiment in figure 11 is somewhat similar to the embodiment shown in figure 10. The main difference being that a stiff conductive metallic sheet 601  
35 has a protruding part 602 extending substantially

parallel to a ground plane means 603 at a first distance 604 from the ground plane means. Said first distance is different from a second distance 605 from a conductive coating 606 to the ground plane means 603. By  
5 designing the planar inverted F-antenna to have surfaces substantially parallel to the ground plane means 603 but at different distances, the antenna can more precisely be tuned to different resonance frequencies for multi band operation. A post 607 is extending from  
10 the conductive coating 606 to the ground plane means 603.

Figure 12 shows a diagrammatic cross-sectional side view of an antenna according to the invention. In this  
15 embodiment a shielded space 701, for mounting circuitry 703 and 704, is formed in the part of the PIFA which is extending orthogonal to a ground plane means 702. A stiff conductive metallic sheet 705 is shielding the space 701 and extending substantially parallel to the  
20 ground plane means 702. An insulated feed line 706 is extending on the sheet 705 for feeding RF energy to a feed point 707.

Figure 13 shows a diagrammatic cross-sectional side view of a further embodiment according to the invention. A first and second feed point 801 and 802 are fed  
25 with RF signals from a first and second feed line 803 and 804, respectively. The first and second feed line 803 and 804 may be feeding transmitting and receiving  
30 RF signals respectively, or may be feeding signals from two different systems, such as GSM and PCN, respectively.

Figure 14 shows a diagrammatic cross-sectional top view  
35 of the embodiment described in connection with figure 13. The same reference numerals are used in figure 14

as in figure 13.

Figure 15 shows a diagrammatic view of another embodiment according to the invention. In this embodiment a GPS antenna is formed using an almost square, but somewhat rectangular, conductive portion 1001 which is fed with an offset from the center, marked with an X, 1002, to produce a circular polarized RF signal. A shielded cavity 1003 is formed in the support structure for mounting of analogue circuits 1004. An edge load 1005 is present to adjust the antenna to the preferred characteristics. The load 1005 make an impedance connection between the conductive portion 1001 and a ground plane means (not shown).

Figure 16 shows a diagrammatic cross-sectional view of a further embodiment according to the invention where a hotwire 1101 is forming the conductive post and is arranged for feeding RF signals to the antenna according to traditional methods. A shielded cavity 1102 is formed inside a support structure 1103 and is arranged for housing circuits 1104 in similar ways as been described earlier.

Figure 17 shows a diagrammatic cross-sectional view of a preferred embodiment according to the invention where the antenna has a smooth curving to follow a contour of a portable cellular phone. A conductive portion 1201 is arranged on a support and is shielding a cavity 1202. Circuitry (not shown) on a circuit board 1203, having a ground plane means 1204 arranged thereupon, is coupled to analogue circuitry 1205 arranged inside said cavity through coupling means 1206 as has previously been described.

For manufacturing purposes, or other purposes, it could

be beneficial to design the cavity as a box having a lid or a hood, or, more generally, as a box having one open side which can, at a convenient time, be covered.

- 5 The conductive portion or coating defining and shielding said cavity need not necessarily be tight but may instead be formed as a net or may comprise a number of holes, as long as the holes is substantially smaller than  $\lambda/4$ , that is, one quarter of the current wave-  
10 length. This will seal the circuitry inside the cavity from the radiation emitted from the antenna device. The cavity can also be filled with a dielectricum.

- The invention being thus described, it will be obvious  
15 that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the  
20 following claims.

CLAIMS

1. An antenna device for transmitting and receiving RF waves in at least a first frequency band and adapted to  
5 be arranged in a radio communication device, comprising,

- a support structure (2; 26; 33),
- 10 - at least one radiating antenna portion (1; 8; 16; 27; 37, 40) carried by the support structure,
- a first circuit (3; 9; 35, 36, 38, 39, 41-44) carried by the support structure for processing  
15 analogue RF signals tapped from or fed to the radiating antenna portion, and
- coupling means being arranged for connecting said first circuit (3; 9; 35, 36, 38, 39, 41-44) to  
20 circuits of the radio communication device,

characterized by

- 25 - a radiation shielding device (4; 28; 46, 47) of an electrically conductive material which at least partially surrounds said first circuit (3; 9; 35, 36, 38, 39, 41-44), and
  - 30 - said shielding device (4; 28; 46, 47) being functionally integrated with said radiating antenna portion (1; 8; 16; 27; 37, 40) to form an actively radiating part thereof.
2. An antenna device according to claim 1, wherein
- 35 - said shielding device (4; 28; 46, 47) is resisti-

vely connected to the radiating antenna portion  
(1; 8; 16; 37, 40).

5 3. An antenna device according to claim 1 or 2, where-  
in

- said shielding device (4) is mounted on a portion  
of the radiating antenna portion (16).

10 4. An antenna device according to claim 1 or 2, where-  
in

- said shielding device is formed by a part of the  
radiating antenna portion (105).

15

5. An antenna device according to any of claims 1-4,  
wherein

20 - said first circuit (9) is electrically connected  
to the radiating antenna portion (16) at a connec-  
tion point located inside the shielding device  
(4).

25 6. An antenna device (4) according to any of claims 1-  
5, wherein

- the shielding device is in the form of a shielding  
can.

30 7. An antenna device according to any of claims 1-6,  
wherein

35 - said first circuit comprises a filter for filter-  
ing RF signals tapped from the radiating antenna  
portion.

8. An antenna device according to any of claims 1-7, wherein

- 5       - said first circuit comprises a filter for filtering RF signals to be fed to the radiating antenna portion.

9. An antenna device according to any of claims 1-8, wherein

- 10       - said first circuit comprises a low noise amplifier for amplification of RF signals tapped from the radiating portion.

15       10. An antenna device according to any of claims 1-9, wherein

- 20       - said first circuit (9) comprises a power amplifier for amplification of RF signals to be fed to the radiating antenna portion (8; 16).

11. An antenna device according to any of claims 1-10, wherein

- 25       - the support structure (2; 26; 33) carrying the radiating antenna portion (1; 8; 16; 27; 37, 40) and said first circuit is designed as an antenna module connectable to a transmitting circuitry and to a receiving circuitry of the radio communication device.
- 30

12. An antenna device according to any of claims 1-11, wherein

- 35       - the antenna device is intended to be connected to a software radio,

- 5       - all analogue components (35, 36, 38, 39, 41-44) of a transmitting circuitry and of a receiving circuitry of the radio device are mounted on the support structure (33) carrying the radiating antenna portion (37; 40),
- said analogue components are surrounded by at least one shielding device (46; 47), and
- 10       - said support structure with the antenna portion and said analogue components forms an antenna module connectable to a signal processor of the software radio via a digital-to-analogue converter and an analogue-to-digital converter, respectively.
- 15       13. An antenna device according to claim 12, wherein
  - 20       - the analogue components (35, 36, 38, 39) of the transmitting circuitry are surrounded by a first shielding device (46), and the analogue components (41-44) of the receiving circuitry are surrounded by a second shielding device (47).
- 25       14. An antenna device according to any of claims 1-13, wherein
  - 30       - the radiating antenna portion is adapted to operate in at least two frequency bands.
- 15. An antenna device according to any of claims 1-14, wherein
  - 35       - the radiating antenna portion comprises a first antenna (37), being a transmitting antenna, and being connectable to transmitting circuitry of the



radio communication device, and a second antenna (40), being a receiving antenna, and being connectable to receiving circuitry of the radio communication device.

5

16. An antenna device according to claim 15, wherein

- the radiating pattern of the first antenna and the radiating pattern of the second antenna have different polarizations.

10

17. An antenna device according to any of claims 1-16, wherein

- said radiating antenna portion (1; 27) comprises a meander shaped antenna element.

15

18. An antenna device according to any of claims 1-17, wherein

20

- said radiating antenna portion (16) comprises a patch antenna element.

19. An antenna device according to any of claims 1-18, wherein

25

- said radiating antenna portion (8) comprises a slot antenna element.

20. An antenna device according to any of claims 1-19, wherein

30

- the support structure (26) has the form of a thin substrate having first and second surfaces, at least a portion of said substrate being curved.

35

21. An antenna device according to claim 20, wherein

- said first antenna and said second antenna are arranged on the concave surface of the carrier,  
5 said surface being the said first surface of the carrier.

22. An antenna device according to claim 20 or 21, wherein

- the carrier (26) is shaped so as to closely conform to the back part of the casing of a portable telephone in which it is to be arranged.

23. An antenna device according to any of claims 20-22, wherein

- the radiating antenna portion is divided into a first part and a second part,  
20
- the first part of the antenna portion being arranged on the first surface of the carrier, and
- the second part of the antenna portion being arranged on the second surface of the carrier.  
25

24. An antenna device according to any of claims 21-23, wherein

- said first circuit is mounted on said first surface of the carrier.  
30

25. An antenna device according to any of claims 21-24, wherein

- said first circuit is mounted in a recess in said  
35

second surface of the carrier and connected to the radiating antenna portion on said first surface of the carrier via through holes in the carrier.

5     26. An antenna device according to any of claims 1-19, wherein

10     - the radiating antenna portion is arranged on the inside surface of a part of the casing of the radio communication device, said part constituting said carrier.

15     27. An antenna device according to any of claims 1-19, wherein

   - the radiating antenna portion is arranged on the inside surface of the back part of the casing of a portable telephone in which it is to be arranged.

20     28. An antenna device according to any of claims 1-27, wherein

25     - an additional radiation shielding device (102) is arranged between a second circuit (103) of the radio communication device and the radiating antenna portion (105).

   29. An antenna device according to claim 28, wherein

30     - said additional radiation shielding device (102) includes a ground plane means.

   30. An antenna device according to any of claims 1-29, comprising a ground plane means.

35     31. An antenna device for receiving and transmitting

RF signals in at least a first frequency band comprising:

- 5       - a support structure (104),
- a ground plane means (102),
- 10       - at least a first radiating conductive portion (105) extending above said ground plane means at a first distance from said ground plane means and being electrically coupled to said ground plane means,
- 15       - a conductive feeding post (113) extending between said first radiating conductive portion and said ground plane means,

characterized in, that

- 20       - said first radiating conductive portion is forming at least a first cavity (114) comprising at least a first opening,
- 25       - coupling means (106) being arranged for connecting a second circuit to at least one first circuit (110) arranged inside said cavity through said first opening.

32. An antenna device according to claim 1 or 31, comprising

- 30       - a ground plane means (102),
- 35       - at least a first conductive portion (105) forming at least one radiating antenna portion, and extending above said ground plane means at a first

distance from said ground plane means and being electrically coupled to said ground plane means, and

- 5        - a conductive feeding post (113) extending between said first radiating conductive portion and said ground plane means, wherein
- 10       - said first radiating conductive portion forms at least a first radiation shielding cavity comprising at least a first opening,
- 15       - said first circuit is arranged inside said cavity, and
- 15       - said coupling means are arranged for connecting said first circuit to said circuits of the radio communication device through said first opening.
- 20       33. An antenna device according to claim 32, wherein
- 25       - at least a first feeding means (111) is extending through said opening and being coupled to said conductive feeding post at a feeding point (112) above said ground plane means,
- 30       - said feeding means being arranged for being coupled to RF circuitry for feeding RF signals to said feeding point.
- 35       34. An antenna device according to claim 32, wherein
- 35       - said conductive post is a hotwire (1101) for feeding RF signals from RF circuitry to a feeding point on said radiating conductive portion above said ground plane means.

35. An antenna device according to any of claims 32-34, wherein

- 5       - said first radiating conductive portion extending at least partly substantially parallel over said ground plane means.

36. An antenna device according to claim 33 or 35, wherein

10

- said conductive post extending towards said ground plane means from said first radiating conductive portion.

15       37. An antenna device according to any of claims 32-36, wherein

- 20       - said ground plane means having a second opening adapted to fit to said at least first opening,
- 25       - said coupling between said first radiating conductive portion and said ground plane means being achieved by coupling substantially the complete rim of said at least first opening to substantially the complete rim of said second opening in said ground plane means.

38. An antenna device according to any of claims 32-37, wherein

30

- said coupling between said first radiating conductive portion and said ground plane means being achieved through metallic hooks coupled to said ground plane means and exerting a contact force on
- 35       said first conductive portion,

- said hooks further being arranged for fixedly holding said support structure.

39. An antenna device according to any of claims  
5 32-38, wherein

- said coupling means comprises at least a first connector member arranged on said support and at least a second connector member arranged on a  
10 circuit board,

- said first connector member having means for connecting said radiating conductive portion to said ground plane means.

15

40. An antenna device according to any of claims  
32-39, wherein

- said first radiating conductive portion having a  
20 first portion substantially parallel to said ground plane means arranged at a first distance (604) to said ground plane means and a second portion substantially parallel to said ground plane means and arranged at a second distance  
25 (605) from said ground plane means.

41. An antenna device according to any of claims  
32-39, wherein

- said first circuit being selected from a group of  
30 analogue circuits including the following circuits: low-noise amplifier, power amplifier, decoupler, coupler, multiplexer, diplexer, SIM-card, logical circuits, balun circuits, diod, sensing  
35 device and phasing circuits.

42. An antenna device according to any of claims  
32-41, wherein

- 5       - a second feeding means being arranged for feeding  
       RF signals to a second feeding point,
- said second feeding point being in electric con-  
       tact with said at least partly parallel portion,
- 10       - a second conductive post, electrically coupled to  
       said at least partly parallel portion, extending  
       towards said ground plane means and arranged in  
       proximity of said second feeding point.

15       43. An antenna device according to any of claims  
       32-42, wherein

- said conductive post has a circular cross-section.

20       44. An antenna device according to any of claims  
       32-43, wherein

- said conductive post has an elongated cross-sec-  
       tion extending from one side of said at least  
25       partly parallel portion to the opposite side.

45. An antenna device according to any of claims  
32-44, wherein

- 30       - said conductive post has a mechanical interface  
       with said ground plane means so as to make an  
       electrical conductive connection.

46. An antenna device according to any of claims  
35       32-44, wherein



- said conductive post couples capacitively to said ground plane means.

47. An antenna device according to any of claims  
5 32-46, wherein

- said antenna being operative in at least a first frequency band corresponding to at least one of the GSM, PCN, and/or GPS communication bands.

10

48. An antenna device according to any of claims  
32-47, wherein

- said cavity is filled with a dielectricum.

15

49. A radio communication device comprising an antenna device according to any of claims 1-48.

Fig. 1

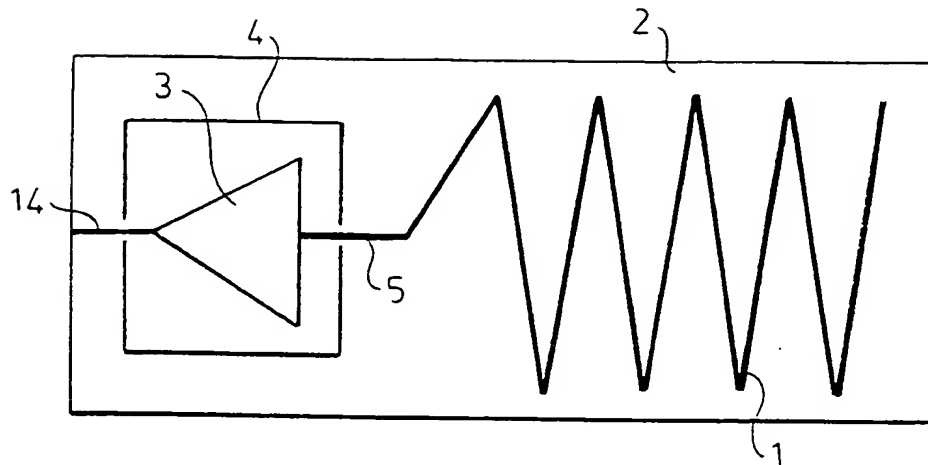


Fig. 2

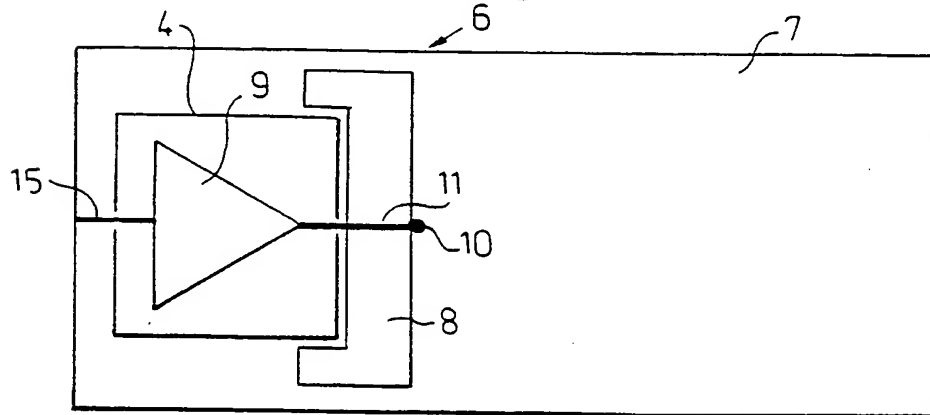


Fig. 3

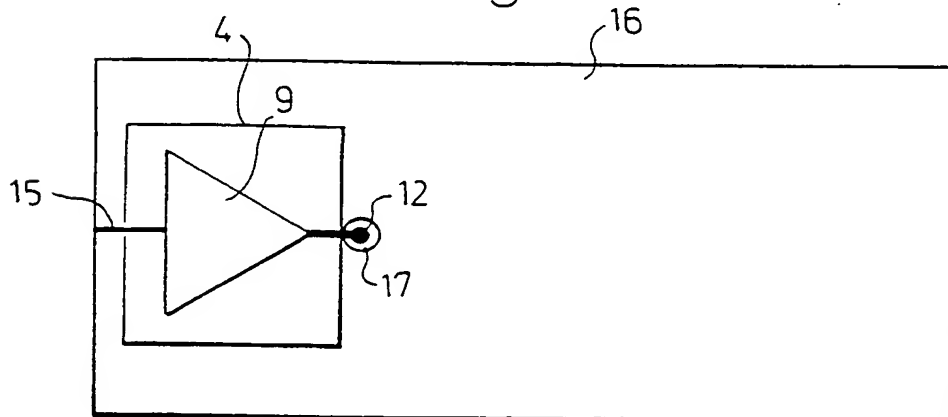


Fig. 1a

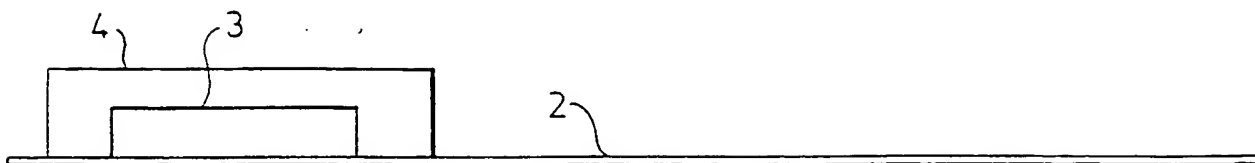


Fig. 1b

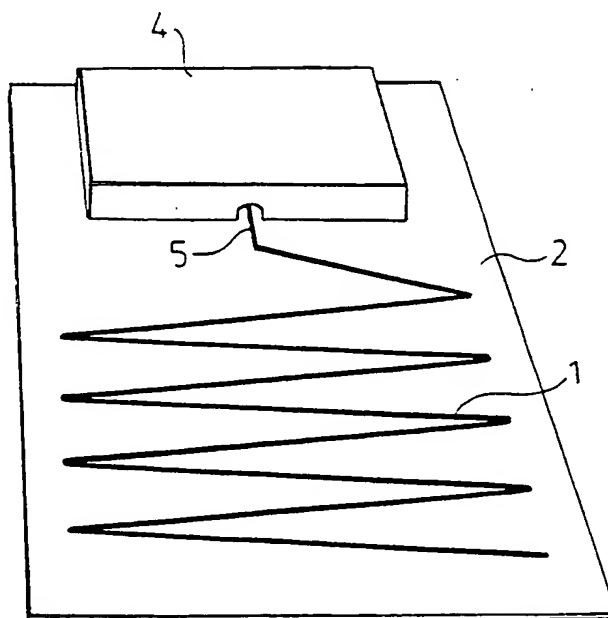


Fig. 4

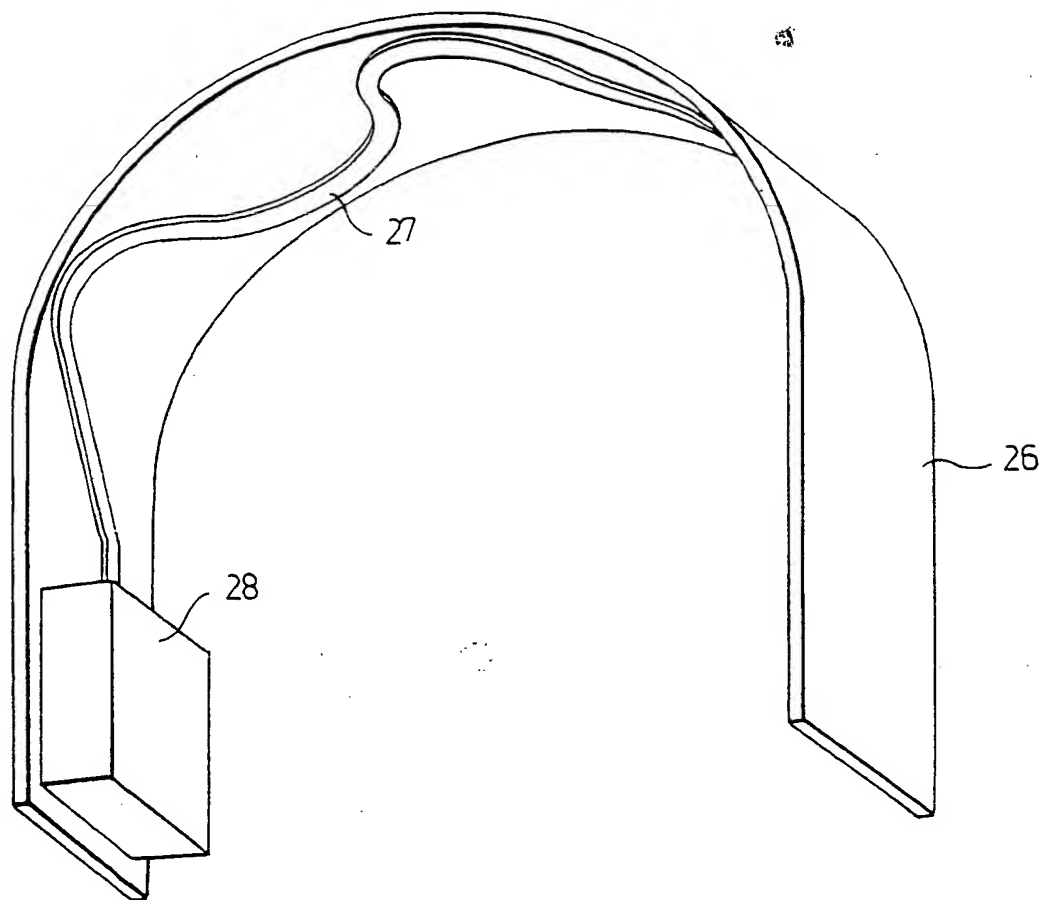


Fig. 5

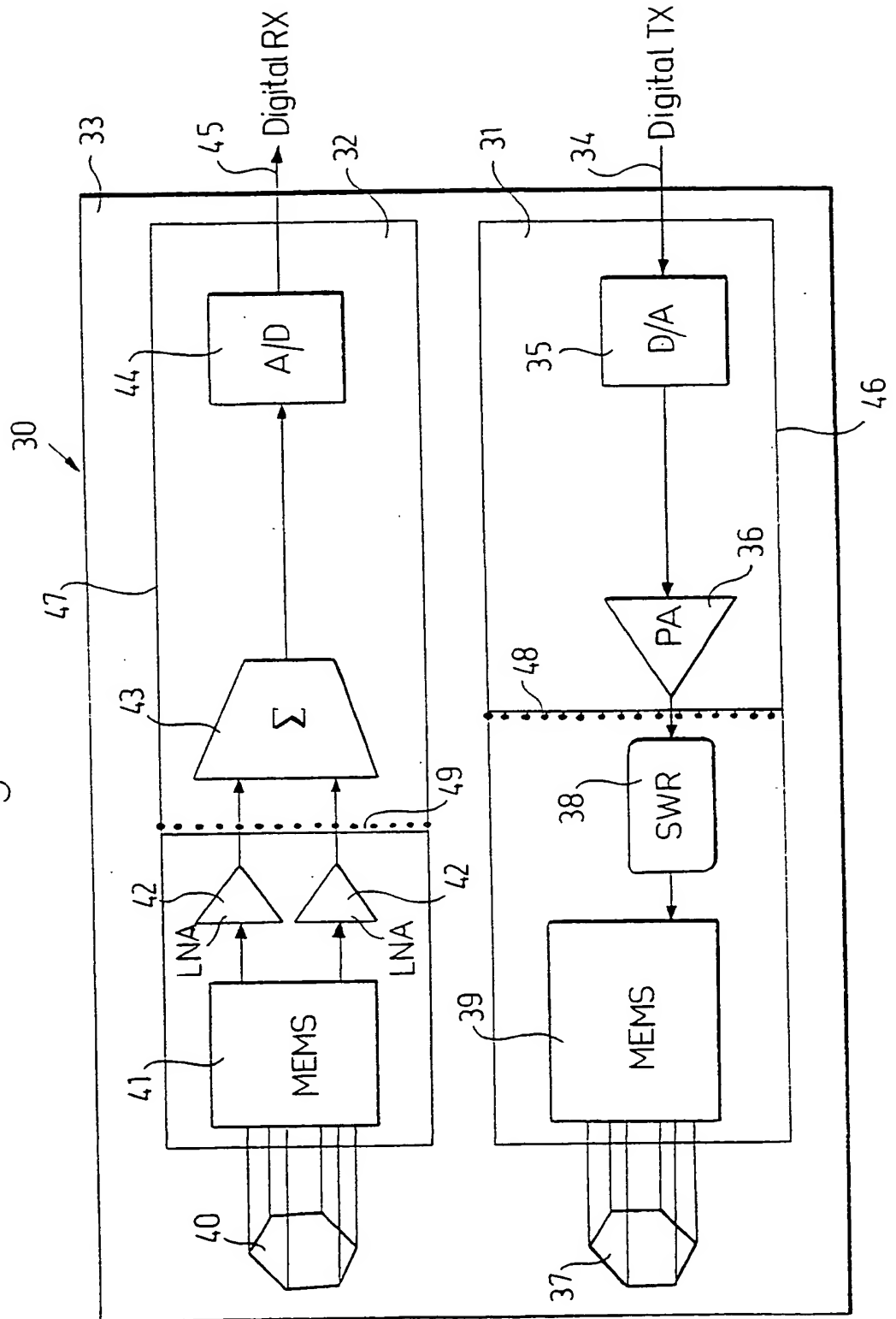


Fig.6

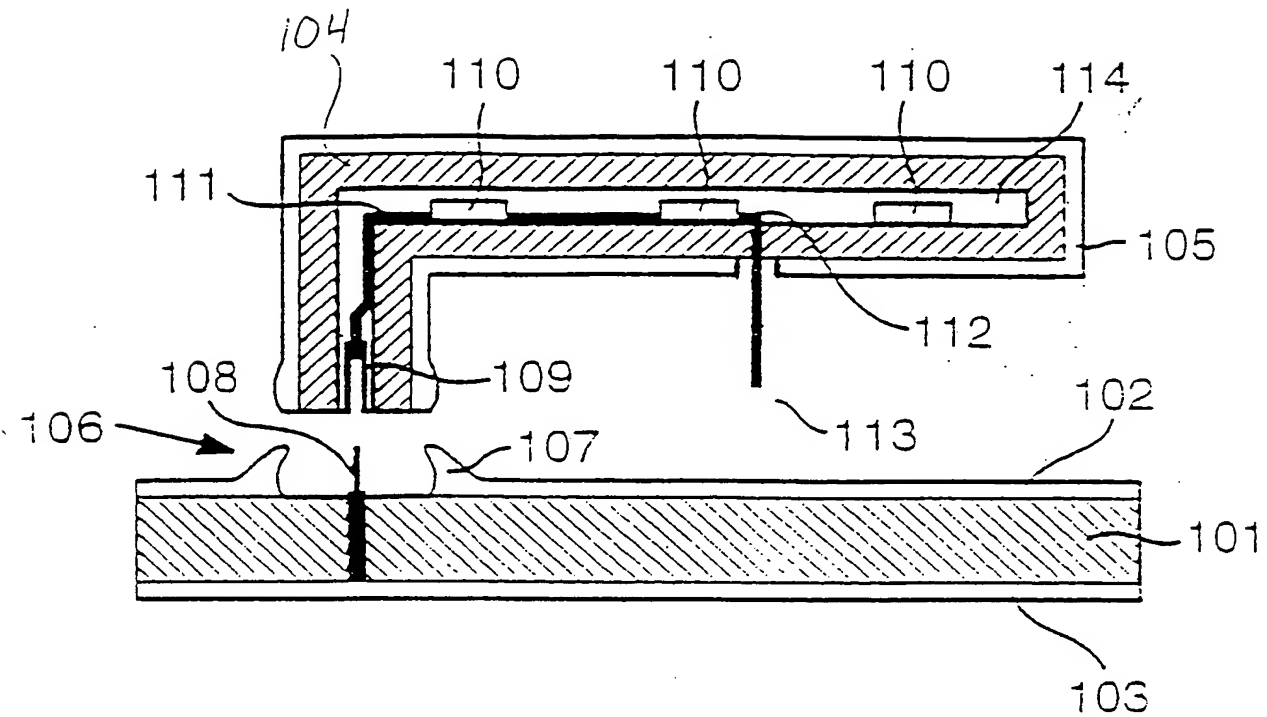


Fig.7

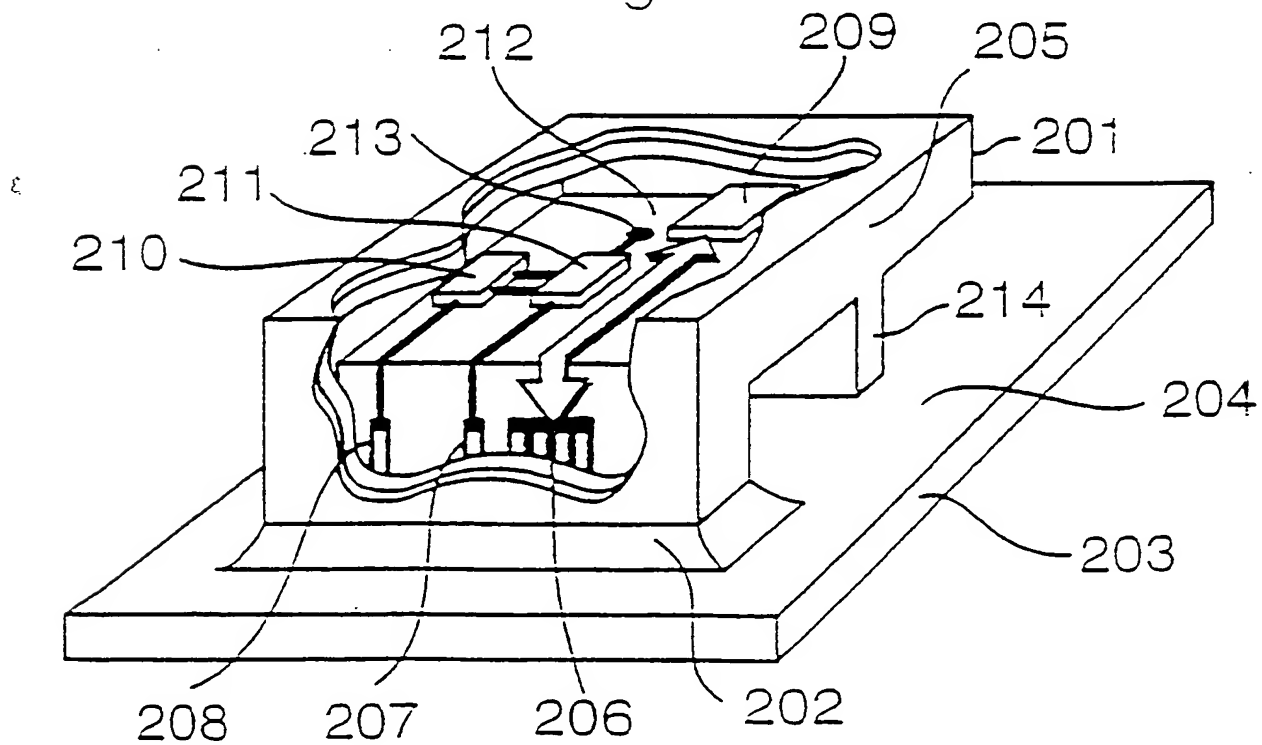


Fig. 8

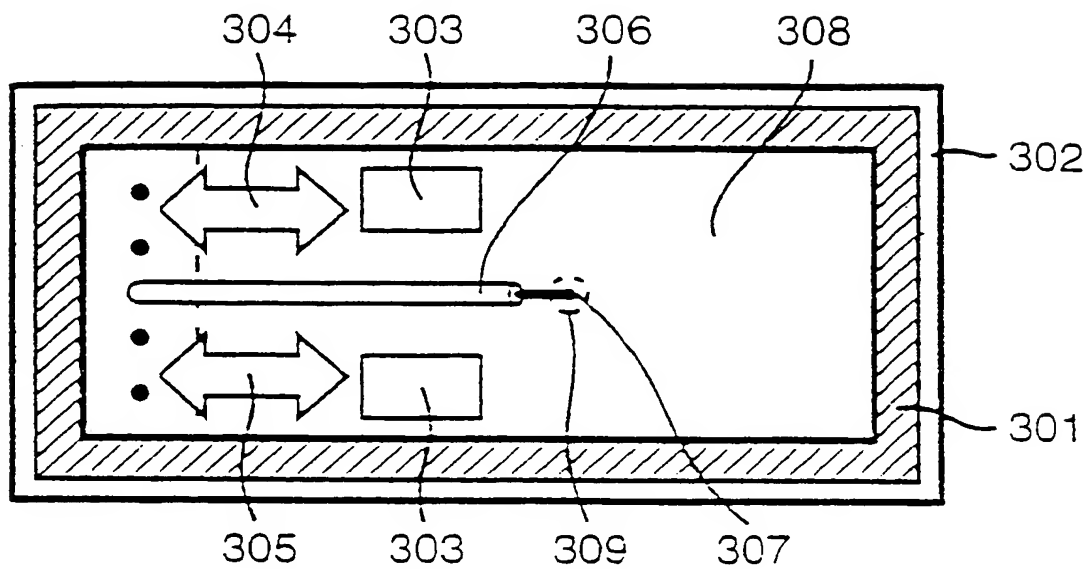


Fig. 9

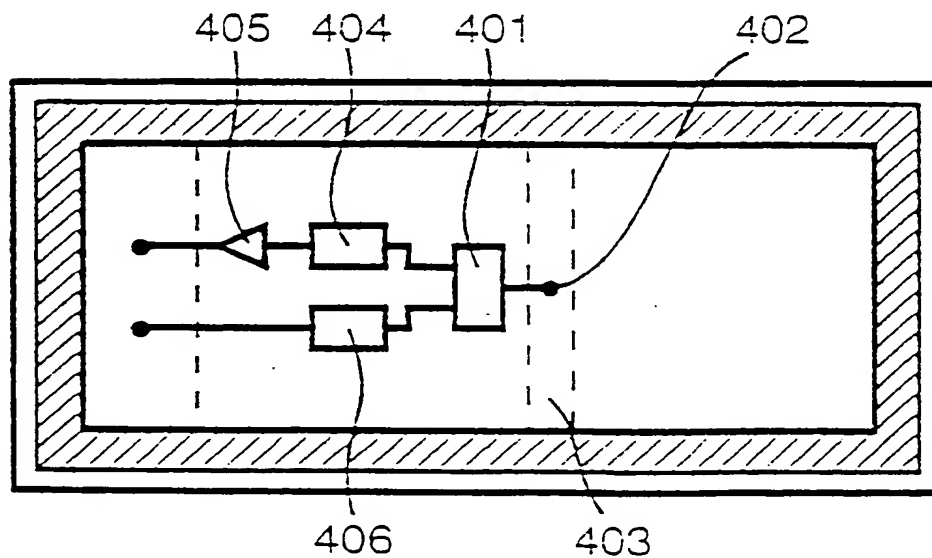


Fig.10

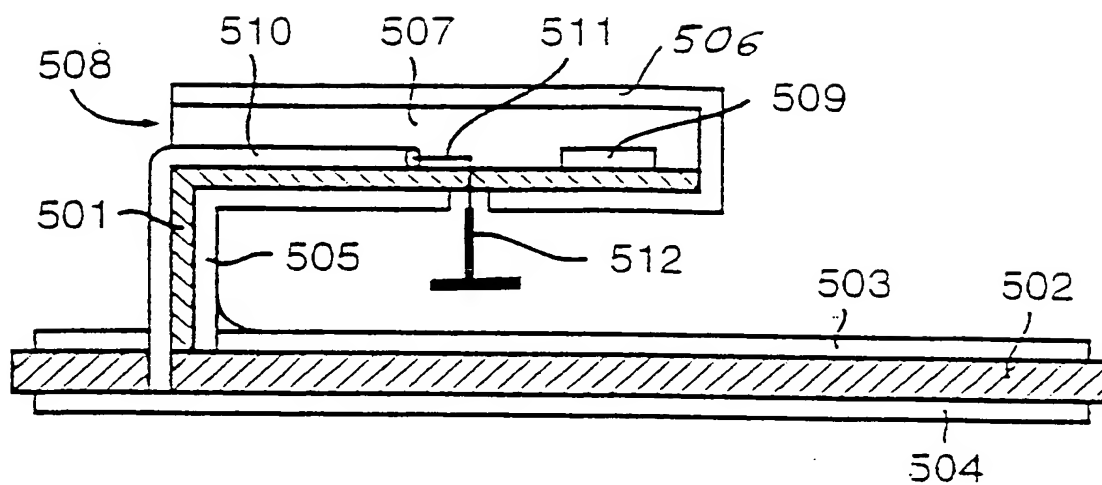
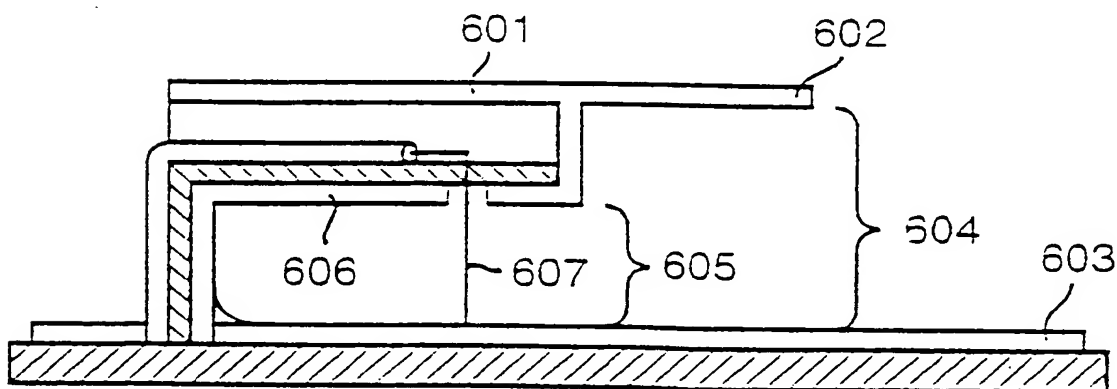


Fig.11





8 / 10

Fig. 12

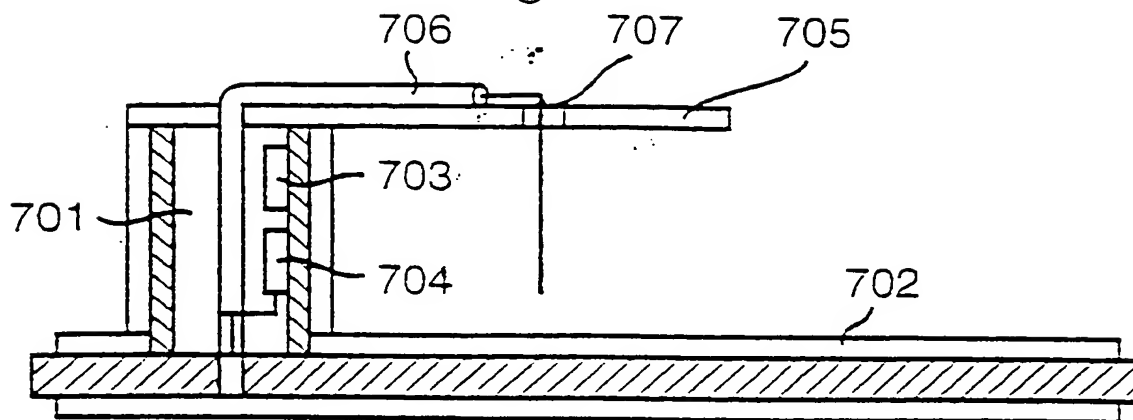


Fig. 13

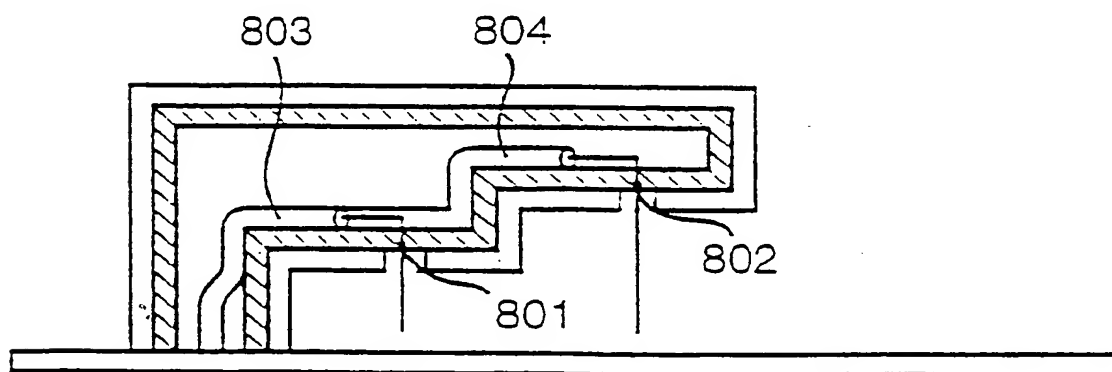


Fig. 14

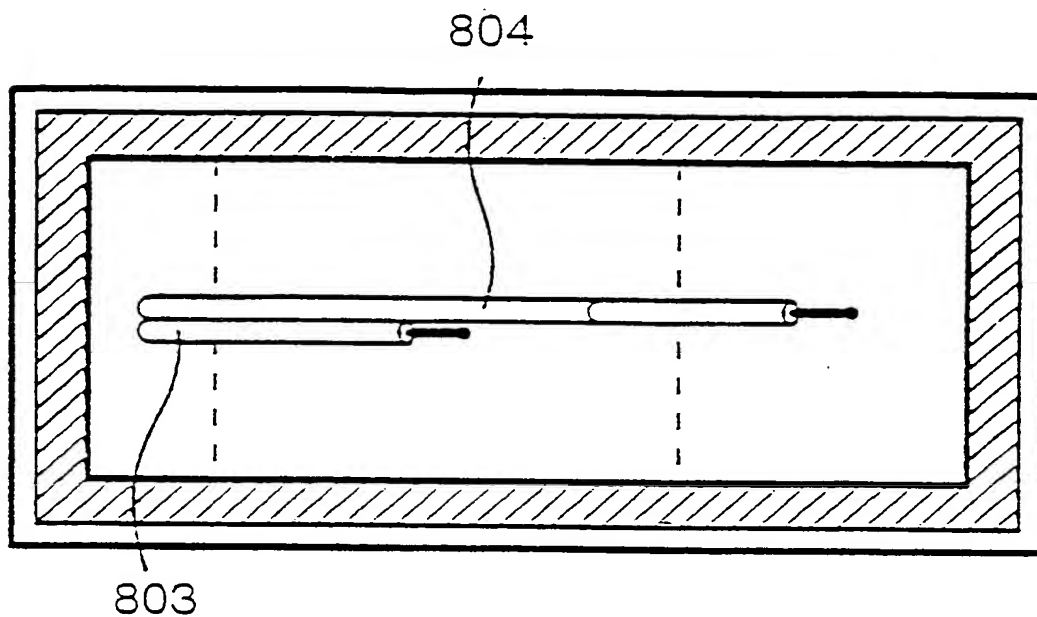


Fig 15

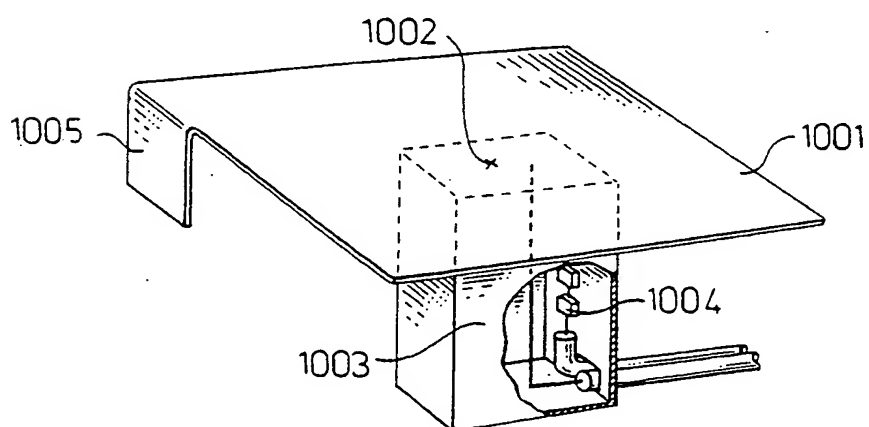


Fig. 16

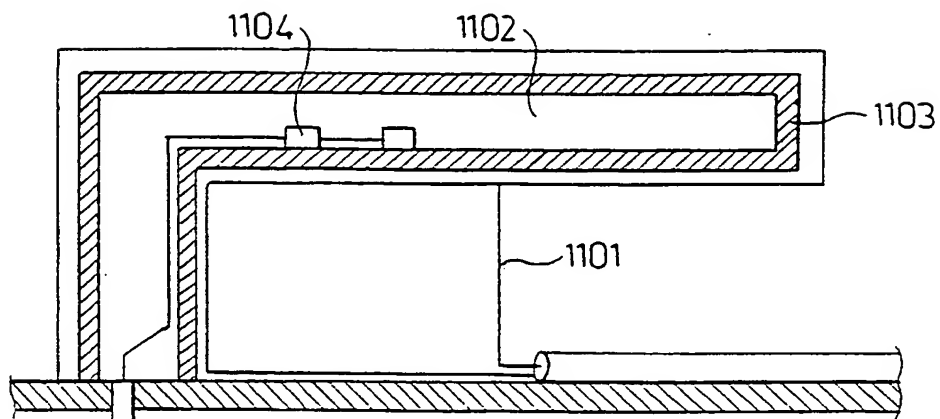
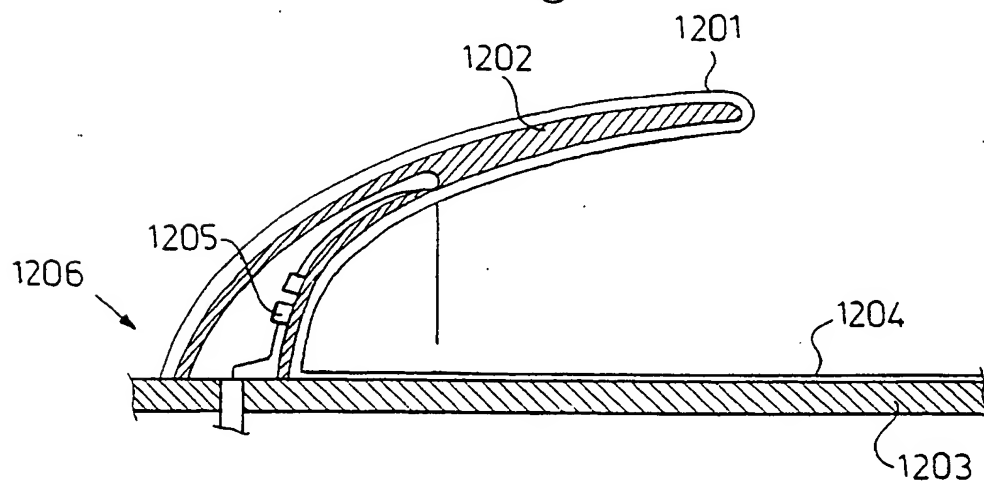


Fig. 17



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 00/00239

## A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H01Q 1/38

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H01Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 9415378 A1 (MOTOROLA INC.), 7 July 1994 (07.07.94), See figure 4 --	1-30
P,A	WO 9940647 A1 (ERICSSON INC.), 12 August 1999 (12.08.99) --	1-30
A	EP 0177362 A2 (NEC CORPORATION ET AL), 9 April 1986 (09.04.86), abstract, figures --	31-49
A	US 4415900 A (CYRIL M. KALOI), 15 November 1983 (15.11.83) --	31-49

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

\* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&amp;" document member of the same patent family

Date of the actual completion of the international search

22 June 2000

Date of mailing of the international search report

05 -07- 2000

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## INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 00/00239

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5355142 A (ROBERT MARSHALL ET AL), 11 October 1994 (11.10.94)  --	31-49
A	US 5448249 A (YUICHI KUSHIHI ET AL), 5 Sept 1995 (05.09.95)  -- -----	31-49

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/SE00/00239

## Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).:

## Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

**Claims 1-30 relating to an antenna device including a radiation shielding device of an electrically conductive material**

**Claims 31-41 relating to an antenna device including a radiating conductive portion forming a cavity**

**The two antenna devices have no common technical features over the prior art.**

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

### Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

**INTERNATIONAL SEARCH REPORT**  
Information on patent family members

International application No.  
**PCT/SE 00/00239**

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